Bouncing Exponentials

Math / Physics
Middle / High
Exponential Regressions / Data Collection

Introduction: Historical rumor states that Galileo dropped objects from the Leaning Tower of Piza to prove that they fell at the same rate. Although this is undoubtedly not a true account, it is true that Galileo did determine that objects of different masses do fall at the same rate. What Galileo did not tell us about was what happened to those objects after they hit the ground. Did they bounce? How high did they bounce? How many times did it bounce? What is the governing mathematical equation for a bouncing object?

In this experiment, you will examine these questions using the Casio EA-100 Data Analyzer connected to a Vernier Motion Detector, and the CFX-9850G or Ga Plus color-graphing calculator.

Objectives: Students will be able to…

1. Collect data by following an experimental procedure.
2. Input data in a graphing calculator.
3. Compare results.
4. Draw conclusions.
5. Determine the governing math model
6. Discuss applications of results.

Related Key Words:

free fall motion	exponential equation	kinetic energy
potential energy	conservation of energy	gravity
elastic collisions	inelastic collisions	

Materials:
CASIO CFX9850-Ga Plus or CFX9850-G COLOR GRAPHING CACLAULTOR
CASIO EA-100 CASIO Data Collector (CDA)
Vernier motion detector
Medium-sized playground ball

<u>Purpose:</u> This experiment involves the collection, graphing, and analysis of data to determine the mathematical model that describes the behavior of a bouncing ball.

<u>STEP 1—</u> Connect the EA-100 unit to the CFX9850-Ga Plus or CFX9850-G calculator with the unit-to-unit link cable using the I/O ports located on the bottom edge of each unit. Press the cable ends in firmly.

<u>STEP 2—</u> Connect the Vernier motion detector to the SONIC port on the right side of the EA-100 unit

<u>STEP 3—</u> Turn the EA-100 on and begin the set-up procedures. Push the gold [SHIFT] key followed by the [MODE] key just below it for SETUP. On the right side of the screen, the words “READY, SAMPLING, and DONE” should be blinking. If they are not, press the [Halt] key next to the red ON/OFF switch, followed by [SHIFT], and [MODE].

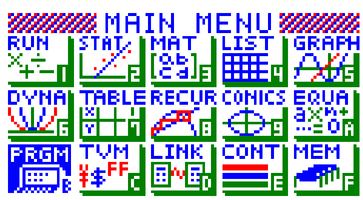
STEP 4— We will set the parameters of the EA-100 to collect 50 data points in 2.5 seconds. The time interval will set to 50.0 msec. Hit the [DATALOG] key for NEXT until this option appears. Press [TRIGGER] for ENTER to store that value. The number of data points will set to 50. Hit the [DATALOG] key until 50 appears. Press [TRIGGER] for ENTER to store that value. Time will be measured as a running clock. Hit the [DATALOG] key until 1 appears. And press [TRIGGER] to store that value. On the right side of the screen READY should appear.

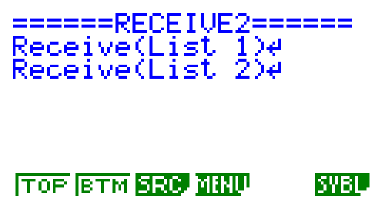
Note: The motion detector cannot detect motion closer than 1.5 feet. Be sure the object is dropped from at least 1.5 meters or you might not have enough data points to develop a model for the motion.

STEP 5— Select three students to perform the experiment and identify them as the "Holder," the "Dropper," and the "Trigger Operator."

- ❑ Holder holds the motion detector above the ball, face down, while it is dropped and bouncing. When the motion detector stops clicking, all data had been collected
- ❑ Dropper: Holds and drops the ball.
- ❑ Trigger Operator: Controls the EA-100 unit.

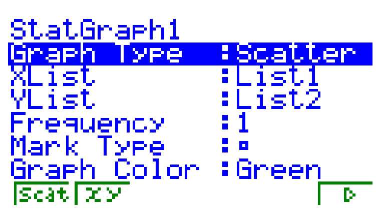
STEP 6— When the EA-100 unit displays READY, the Trigger Operator should press TRIGGER on the EA-100 and tell the Dropper to release the object. Since the EA-100 unit is programmed to only record data for 2.5 seconds, the Dropper should release the object immediately after TRIGGER is pressed. When the Catcher catches it, see if the object fell directly toward the middle of the detector. IF not, restart the experiment from Step 7.

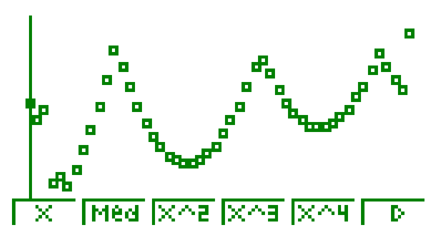




STEP 9— Analyze the collected data on the CFX-9850G OR GA PLUS calculator by using the Receive2 program to transfer the data to the STAT menu on the calculator.

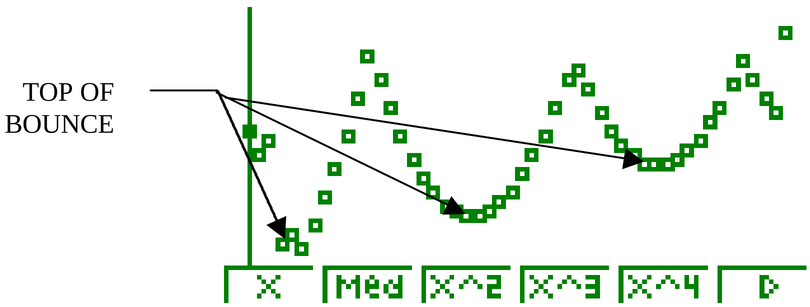
Step 10— The data from the EA-100 is now stored in List1 (time) and List2 (distance). Open the STAT menu and then press [F1] for GRPH. Next, you will need to set-up the graph by pressing [F6] for SET. The window for StatGraph1 should be the same as below.





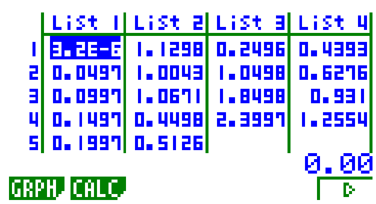
After pressing [EXE], press [F1] for GPH1. You will get a graph similar to the one above.

Step 11— Use the TRACE function, [SHIFT] then [F1], to locate the ball's highest points, which will be the peak of each bounce. Because we are measuring from the drop height down, these points will correspond to the smooth dips in the graph.

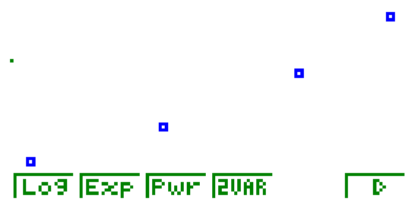


Trace along the graph and locate these points. The coordinates of these points (X = time, Y = distance) will be displayed at the bottom of the calculator screen. Record as many of these data points as possible on your data sheet.

Step 12— Input the new data into List3 and List4 of the STAT menu. In List3, put the number of the bounce, in List4 put the distance. Following the same procedure as in Step 10, set up the StatGraph2 window the same as StatGraph1.



	List 1	List 2	List 3	List 4
1	3.2E-5	1.1298	0.2496	0.4393
2	0.0497	1.0043	1.0498	0.6276
3	0.0997	1.0671	1.8498	0.931
4	0.1497	0.4498	2.3997	1.2554
5	0.1997	0.5126		



Step 13— Graph the new data and perform an exponential regression on the new graph. Copy the equation to the GRAPH menu.

Questions and Problems:

Level 1: Answer the following questions in complete, well-structured sentences.

1. If the governing equation is $y = Hr^n$, where y is the distance of the ball on the nth bounce, n is the number of the bounce, and r is ball's rebound rate, use the data to algebraically determine r.
2. Input this equation into the Graph menu, and using the equation from the data, determine the y intercept for both equations. What does the value of the y intercept represent? Which function best describes the reality of the event? Explain fully.
3. Using the function developed in question 1, what is the total vertical distance the ball has traveled by the tenth bounce? Explain how you derived your answer.
4. Does the initial height effect the bounce rate? Explore by repeating the experiment with at least two other initial heights.
5. Repeat the experiment with different types of balls, such as a tennis, basketball and/or a soccer ball. How is the value of r effected?
6. Trace the relationship of kinetic and potential energies through out this experiment.

Level 2:

1. Identify three sources of error for this experiment.
2. How would the data look different if you were dropping the ball over the motion detector?
3. Why does the ball eventually stop bouncing? Explain in detail.